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MINING SOFT HEMATITE AT MINE NO. 2 OF THE MARQUETTE RANGE, MICHIGAN

BY

LUCIEN EATON

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MINING SOFT HEMATITE AT MINE NO. 2 OF THE MARQUETTE RANGE, MICHIGAN[1]

By Lucien Eaton [2]

INTRODUCTION

This paper describing the mining practices at Mine No. 2 of the Marquette Range, Michigan is one of a series being prepared by the Bureau of Mines on mining practices, methods, and costs in the various mining districts of the United States. The publication of this information should be of interest to the industry at large, and the exchange of ideas thereby made possible should be of economic value to operators in all parts of the country.

ACKNOWLEDGMENTS

The author is indebted to the superintendent, engineer, and mining captain of the property discussed in this paper for much of the information presented. The geological classification is taken from publications of the U. S. Geological Survey.

HISTORY

The Marquette Range was the first iron range discovered in the Lake Superior District. Ore was discovered by surveyors making land surveys for the Federal Government in September, 1844, and the first commercial ore body, later the Jackson Mine, was discovered in September, 1845, by Marji Gesick, a Chippewa Indian chief, who showed the outcrop to explorers.

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1 - The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from U. S. Bureau of Mines Information Circular No. 6179."

2 - One of the consulting engineers, U. S. Bureau of Mines.

For many years after the first discovery only the hard ores, hard specular hematites of high iron content, were sought, but after the Civil War some attention was paid to the hydrous hematites or soft ores, which later became the principal output of the region.

Mine No. 2 was discovered by diamond drilling in 1907 and 1908, and the first shaft was started in 1909. Operation of the mine has been continuous since then.

GEOLOGY

The rocks in the district are pre-Cambrian, and in most places are overlaid by thick glacial deposits consisting of quicksand, sand, and gravel of Pleistocene age.

The Marquette Range consists of a large syncline extending westward from Marquette on the shore of Lake Superior to Michigamme, a distance of 36 miles. The productive part of the range, however, extends only from Negaunee, 9 miles from Marquette, westward for 10 miles. Only one mine is now active at the west end of the range, although there have been large producers in this part of the range in former years.

The formation in which the soft ores occur is the Negaunee formation of Middle Huronian age. This formation consists of ferruginous cherts and slates through which dikes and sills of diorite have been intruded. These intrusions are especially important in the central part of the range in and around Ishpeming. The footwall formation for the main ore bodies is the Siamo slate, a thick layer of slate containing some cherty and ferruginous phases.

The ore at this mine occurs in troughs and folds as more or less lenticular masses, sheets, and chimneys, in troughts and basins formed by faults and folds in the slates or between the slates and dikes. There are over 70 known ore bodies.

The dip of the formation is fairly steep at the surface and becomes flatter at depth, as shown by deep diamond-drill holes.

The shape, size, and position of the ore bodies, as well as the character of the ore and of the overlying rocks, have had much to do with the selection of the mining methods used, and the scattered occurrence of the ore bodies has materially increased the amount of development work required. At one end of the mine a large ore body was found to lie just under the sand, and was of such size and shape that it was feasible to strip the ore and mine a large percentage of it with steam shovels.

PHYSICAL CHARACTERISTICS OF THE ORE AND ENCLOSING ROCKS

The ore is a soft, hydrated hematite, generally reddish brown in color. Some of it is very high grade, but some contains silicious material to such an extent that it is classed as a silicious ore. The high-grade ore generally requires timber to support all but the smaller openings, but the silicious ore often stands well even in large stopes. The ore can all be drilled with auger drills.

The overlying jasper is fairly hard and usually stands well, so that open stopes can be used where the ore is narrow. This jasper consists of alternate bands of ferruginous chert and cherty hematite, and in places the change from jasper to ore is very gradual, so that the limits of the ore are commercial.

The slate underlying the ore is fairly friable, and drills and breaks readily, but, as it stands at a high angle, little timber is required in drifts through it.

The larger dikes are altered diorite or diabase, and where they occur in the wall, rocks are not badly weathered. In the ore, however, the smaller dikes are badly decomposed and do not stand well when exposed to the air. They must be carefully sorted from the ore as it is mined.

The characteristics of both the ore and the enclosing rocks, as well as the shape, size, and position of the ore bodies, have had much to do with the applicability of the mining methods selected.

GENERAL ITEMS

The mine is served by the Lake Superior & Ishpeming Railway with an ore dock on Lake Superior at Marquette, 19 miles away, and also has connections with the Duluth, South Shore & Atlantic Railway which has a dock at Marquette, and with the Chicago & North Western Railway which has a dock at Escanaba on Lake Michigan, 73 miles away. Transportation by water from these ports to Lake Erie ports and to the Chicago district is open from April 15 to November 15, but during the rest of the year all the ore hoisted is dumped on stockpile, except that used by local charcoal furnaces. On account of its physical characteristics, the ore from this mine is particularly suitable for charcoal iron furnaces, and a large tonnage is consumed by them each year. For this trade the ore is crushed at the mine to 2½ inches.

METHODS OF PROSPECTING AND EXPLORATION

On account of the overburden of glacial material, few, if any, outcrops of ore formation are available as aids in prospecting, but some of the rocks of the footwall series do outcrop, and have assisted in determining the geological structure and in locating the position of the iron formation. Geological surveys are followed by magnetic surveys, and these in turn by diamond-drilling.

Much of the ore was found by diamond-drilling from surface, and the diamond drill has also been extremely useful underground.

Underground prospecting has been done principally by drifting and raising, however, with diamond-drilling as an adjunct. Long drifts have been driven in the footwall near the contact with the ore formation, and from these drifts diamond-drill holes are driven at frequent intervals across the iron-formation to the hanging wall. When an ore body is found it is developed by crosscuts, drifts, and raises.

On account of the large amount of drifting required to reach the scattered ore bodies, the level interval is large, and this makes the prediction of the position of the downward extension of developed ore bodies on one level very uncertain on the next level.

METHODS OF SAMPLING AND ESTIMATION OF TONNAGES AND VALUES

Prospecting and development drifts and raises are surveyed geologically, the formations mapped, and when in ore are sampled at 5-foot intervals. These samples and those from diamond-drill holes are recorded on maps and cross sections, and from them the outline and analysis of commercial ore bodies are determined.

A factor of 12 cubic feet per ton is used in calculating ore developed, and a deduction of 10 per cent for incidental rock and 10 per cent for loss in mining is made.

Three grades of ore are mined, two non-Bessemer standard ores, carrying 59 per cent iron dried and 0.100 and 0.120 phosphorus, respectively, and a silicious ore carrying 51 per cent iron, 0.080 per cent phosphorus and 17 per cent silica.

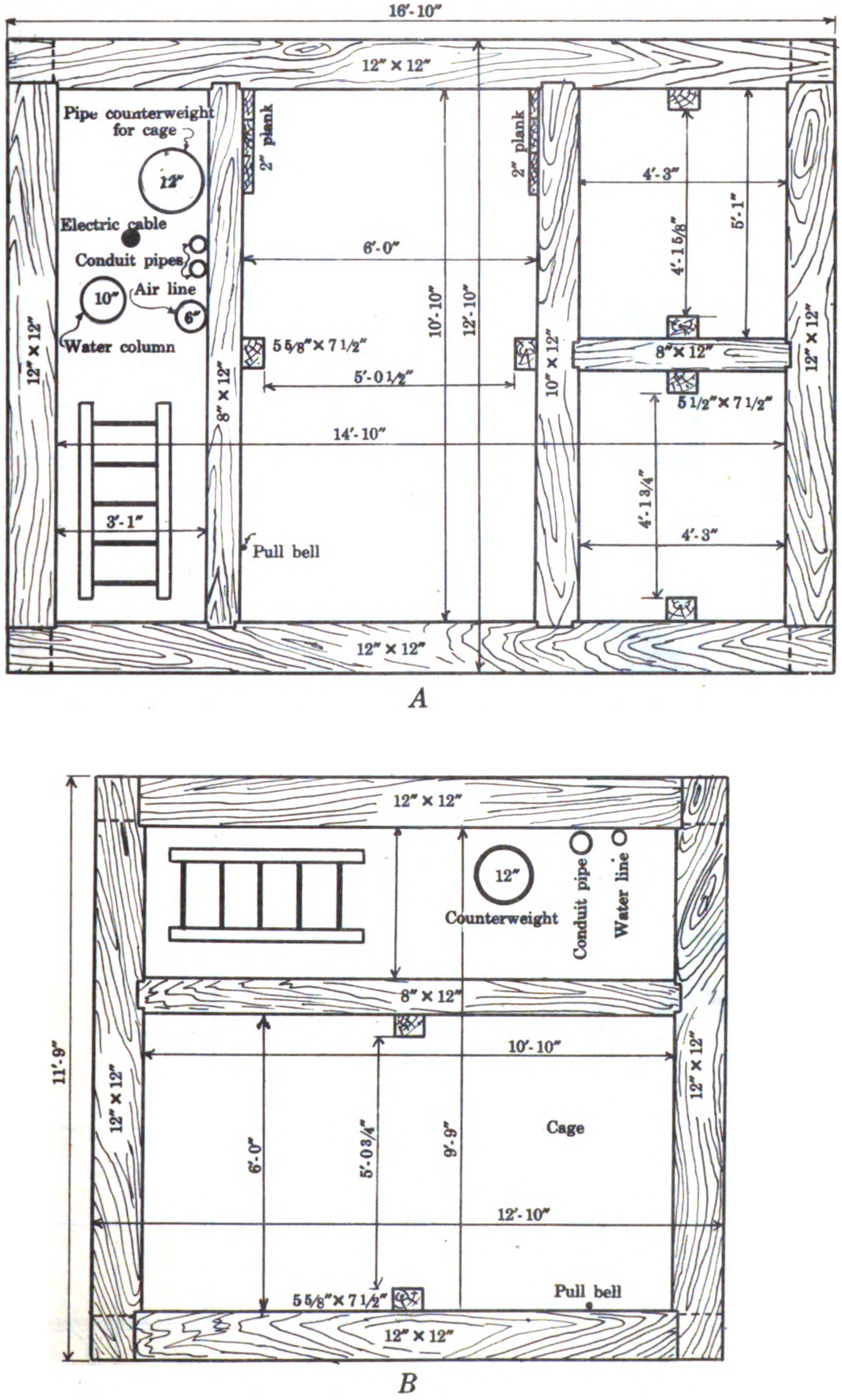

Figure 1.—Arrangement of shafts. *A*, No. 1 and No. 2 shafts; *B*, No. 3 shaft

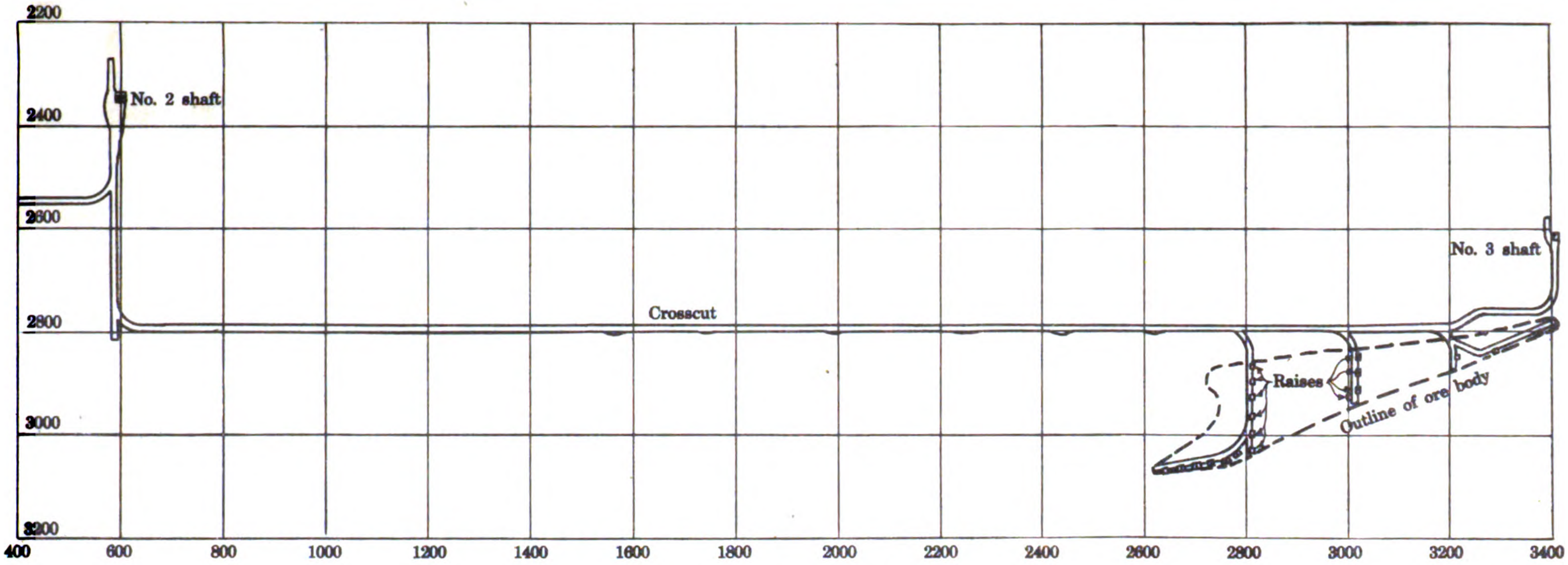

Figure 2. – Plan of a main level

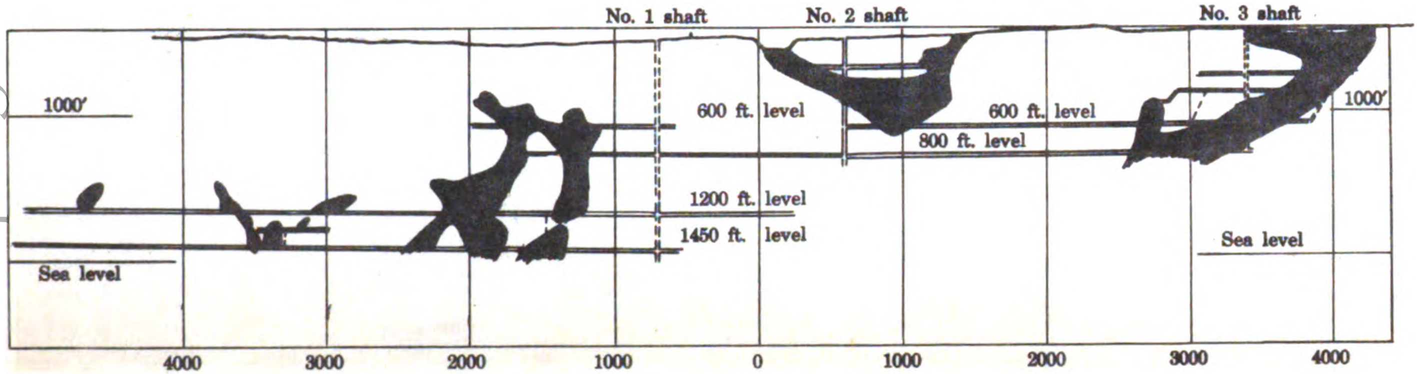

Figure 3. – Longitudinal projection of mine

METHODS OF DEVELOPMENT AND MINING

General Development. - The mine is opened by three vertical shafts, which we will designate as No. 1, No. 2 and No. 3. Figure 2 is a plan of a main level and Figure 3 is a longitudinal projection of the mine showing the size, shape, and positions of the ore bodies and the various levels required for their development.

No. 1 shaft was sunk first, and is now 1,730 feet deep. It was sunk as a circular, concrete, drop shaft through 95 feet of quicksand to the ledge, and it is timbered the rest of the way. This shaft is of the size and shape standard with the company, and its arrangement is shown in Figure 1. It is 10 feet 10 inches by 14 feet 10 inches inside of timbers, and contains two skip roads at one end, a large cage road in the middle and a compartment for ladders, pipes, cables, and counterweight at the other end.

Levels are turned off as follows:-

First level	-	600 feet
Fourth level	-	800 feet
Sixth level	-	1,200 feet
Seventh level	-	1,450 feet
Eighth level	-	1,650 feet

No. 2 shaft is 1,250 feet east of No. 1 shaft. It is of the same size and shape as the lower part of No. 1 shaft. It is, however, timbered throughout. It is close-timbered to the ledge, a distance of 30 feet, and below this point the sets are 6 feet apart on centers.

This shaft is 875 feet deep, and has levels as follows:-

First level	-	200 feet
Second level	-	350 feet
Third level	-	600 feet
Fourth level	-	800 feet

No. 2 shaft is connected with No. 1 shaft on the fourth level.

Both No.1 and No. 2 shafts have steel headframes, and each is equipped with two 4-ton skips and a large cage 4 feet 10 inches by 10 feet 4 inches in floor area. The skips are hoisted in balance and the cage is counterbalanced by a cast-iron circular counterweight running inside a 12-inch pipe.

No. 3 shaft is 2,800 feet east of No. 2 shaft, with which it is connected on the third and fourth levels at depths of 650 and 860 feet. This shaft has been used only as a manway and supply shaft, and for ventilation and outlet. No ore has been hoisted through it. It is equipped with a cage and counterweight. A plan of this shaft is shown in Figure 1.

Development Details. - Some very good drifting records have been made at Mine No. 2, average progress of 400 to 500 feet a month being usual practice. The standard drifts are 10 by 10 feet in cross section.

The round drilled is shown in Figure 4. The whole round is drilled, and the holes are then blasted at one time, using fuse. As soon as the smoke is blown out, mucking is started with an air driven, dipper type Armstrong loader, which discharges directly into 36-cubic-foot rocker-dump cars. Drilling is carried on at the same time as the mucking. Two 3½-inch, wet, mounted hammer drills, using 1¼-inch hollow round steel with lugs, are mounted on a 4-inch single screw bar, set up across the drift. Two rounds are drilled and blasted in each shift of 8 hours.

The crew consists of three miners, a shovel operator, a motorman, and two trammers.

Sixty per cent low-freezing, ammonia gelatin in 1¼ by 8 inch sticks is used in blasting.

The standard raises in the ore are cribbed and have two compartments of the same size. The cribbing is round and is cut 5 feet 4 inches long overall. It is 6 to 8 inches in diameter. Each compartment is timbered separately, so that there are two thicknesses of timber in the center. One compartment is used as a chute and the other as a ladder way and timber slide.

When the raise is put up from a main haulageway, a hinged slide is attached to the bottom set in the ladder road, the hinges being on the side farthest from the drift. This is made of 2-inch plank and is so constructed that, when the bottom ladder has been removed, it can be swung into place as a chute bottom, parallel to the main-chute bottom. Stopper boards are dropped into place in front, and it becomes a chute of small capacity to catch the dirt that falls down the ladderway at every blast while the raise is being put up. This arrangement prevents the spilled dirt from falling on the track and delaying traffic.

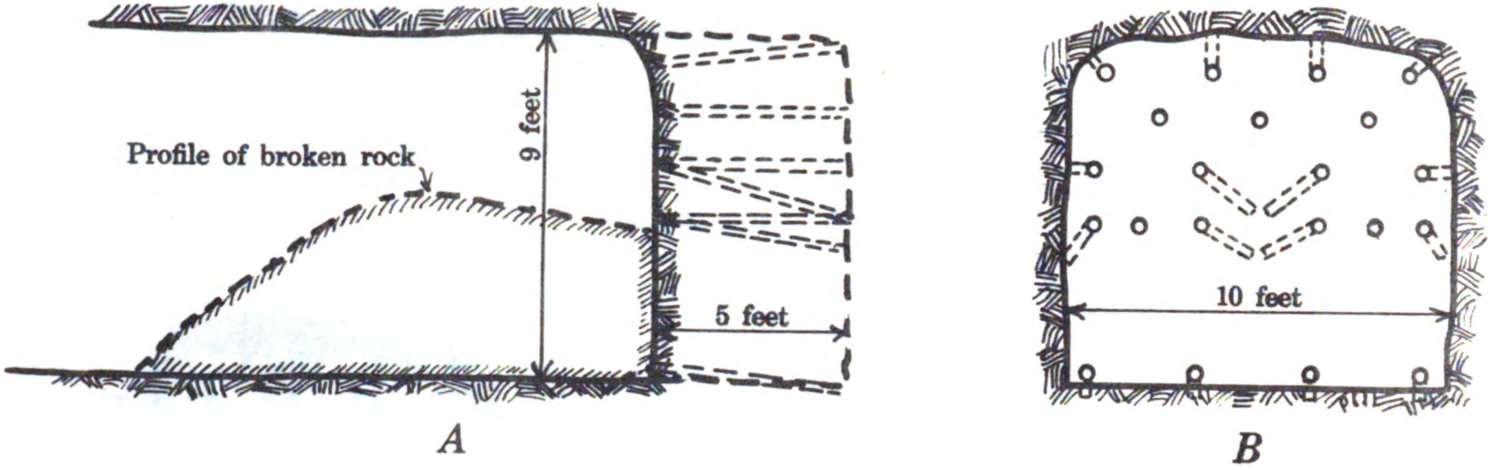

Figure 4.- Rock drift cut. *A*, Vertical projection; *B*, face of breast

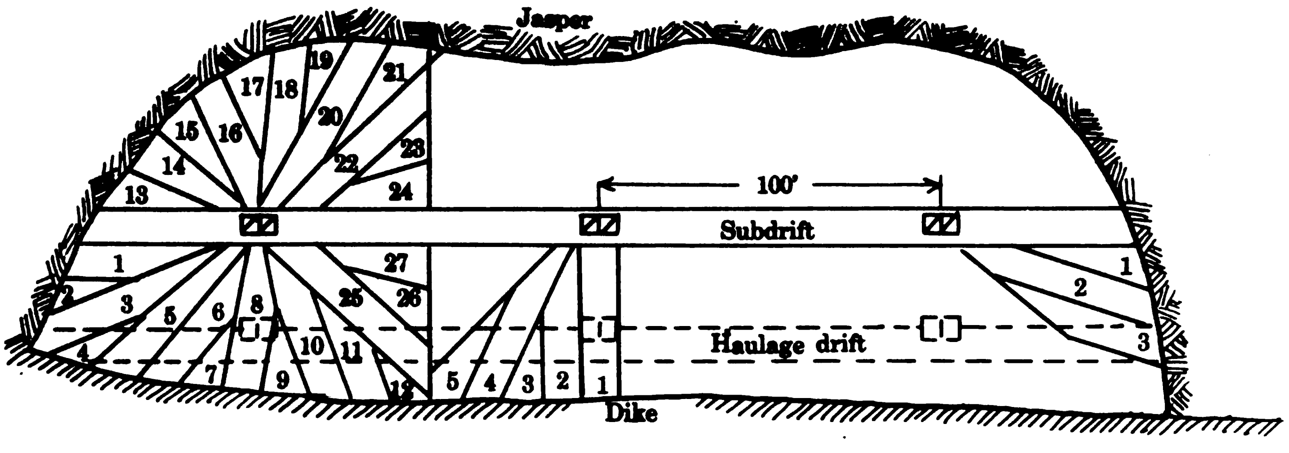

Figure 5.- Top-slice mining method showing radial slicing

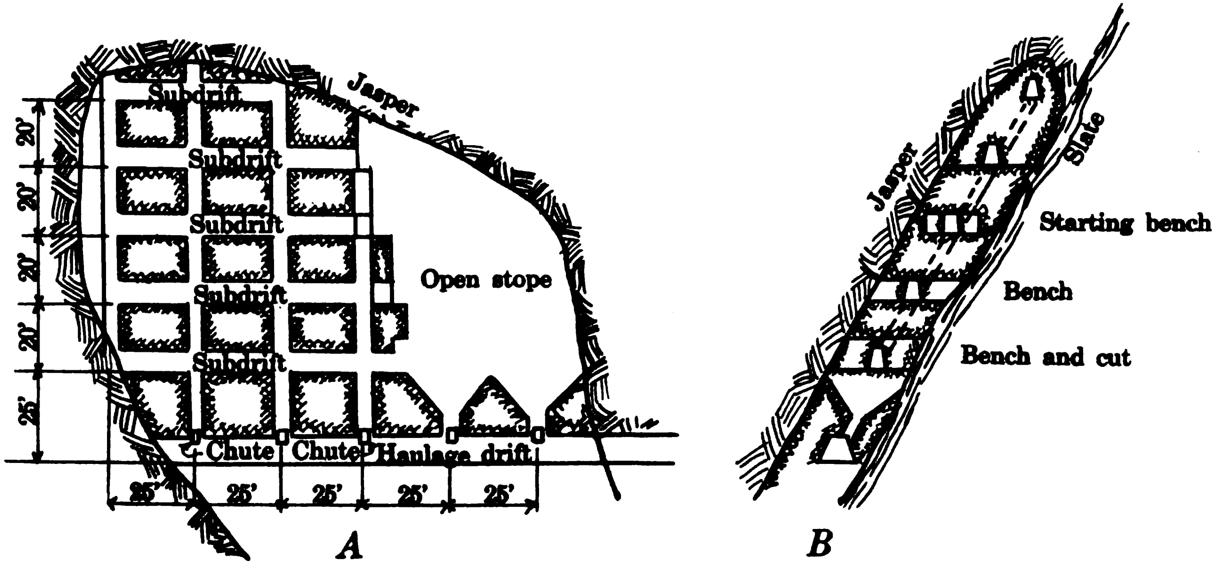

Figure 6.- Substope mining method. *A*, Longitudinal projection; *B*, cross section

STOPING

Two methods of stoping are used. In the wider and softer ore bodies the ore is mined by top-slicing, and in the narrow ore bodies, which stand at a high angle and have fairly strong walls, substopes are used.

TOP-SLICING

The ore body is opened by two-compartment, cribbed raises, put up at an inclination of 65 to 75°. They are spaced usually 50 to 100 feet apart on centers, and are carried to the top of the ore body. Ten to 15 feet below the top of the ore body a sublevel is turned off and the raises are connected. Slices 10 feet high are then taken by radial drifts from the top of each raise, as shown in Figure 5. First a side-slice is driven along one side of the longitudinal drift and a second side-slice is carried alongside it. Both are timbered with 3-foot round timbers and are carefully lagged. The second slice is not full width close to the raise. A third slice, and perhaps a fourth, is taken out, and as soon as the timbers show that they are taking weight they are blasted down, except close to the raise. The floor in each slice is carefully covered down as soon as the slice is finished, using 3½-inch round poles 9½ feet long laid side by side in the drift and overlapped 2 feet at each end. These are covered crosswise with 8 foot lagging on the two top sublevels, but not on the lower subs.

This method of side-slicing is carried on until all the ore on this sublevel within the stoping area of the raise has been mined out. The miners then cut out in the raise 10 feet lower down, and repeat the process, taking out at each blast the full height of the ore up to the covering poles of the first sublevel.

The ore is drilled with auger drills of the jackhammer type, using twisted auger steel of diamond section 1½ inches by 7/8 inch on the center lines. Three rows of holes are required, three in the top row and four each in the other two.

Sixty per cent gelatin is used in blasting.

The ore is hauled to the chute with scrapers of the hoe-type, 42 inches wide, weighing 325 pounds each. The hoists have two drums and are driven by 7½ and 10 hp. motors. Every working place is supplied with from two to four long extension cords with 50-watt lamps attached, and every chute is guarded by a grizzly made of rails set 10 inches apart. When scraping is not in progress, the chute is covered.

The features of the mining method that deserve special mention are:

1. The 10-foot sublevel interval, which promotes safety and complete extraction.
2. The thoroughness with which the floor of each slice is covered down. This prevents contamination of the ore below by broken rock from above, and promotes safety by affording complete protection for miners working on the next sublevel below.
3. The liberal use of electric lights, which promotes both safety and efficiency.
4. The use of strong explosives which shatter the ore so that it is easily handled with the scraper.
5. The type and size of the scraper and hoist used. The scraper blocks are of substantial construction and are made at the mine. The sheaves in them are made of manganese steel, 5½ inches in diameter in the groove, and are 2 inches wide. They are brass- bushed and have a 1½-inch bore. The hauling rope is one-half inch in diameter and the tail-rope three-eighths inch. The tail block is hung from an eyebolt of special design, which is shown in Figure 7. It is inserted in a drill hole in the breast, and is made fast by the wedges on the sides. It is so designed that it does not bind in the hole nearer than 6 inches from the collars.

SUBSTOPING

In the narrow, steeply dipping ore bodies, substopes are used as often as possible. If the ore extends upward from a main level, a drift is driven lengthwise through the ore, and raises are put up at 25-foot intervals on the footwall side to the first sublevel, which is 25 feet above the floor of the main level. The main level is timbered and in every raise but one a chute is built. The raise without a chute is used as a manway and supply raise. This raise is timbered.

The raises are continued to the top of the ore, and are connected on successive sub-levels at 20-foot intervals. The arrangement is shown in Figure 6. Raises are not timbered.

Stoping starts on the first sublevel in the raise farthest from the supply raise. The raise is opened out into an inverted cone for the full width of the ore body, usually 14 to 25 feet, and uppers are then drilled in the back around the raise and are blasted. The process is repeated on successive sublevels until the stope has been opened to the top of the ore. Starting now on the top sublevel two vertical rows of horizontal holes are drilled in the side of the sublevel drift at right angles to its axis and are blasted. This leaves room enough on the bench thus formed to drill long holes both ways from the drift to reach the walls. When these are blasted there is a cut 7 feet high all across the ore body. A double row of upper-holes is now drilled and blasted in the brow over this cut, leaving room for 10-foot holes in the remaining brow above. This process is repeated on successive sublevels downward, the face of the ore being kept at an average angle of about 80°, sloping away from the chute. Drilling is done with auger drills and stopers.

A variation of the method is used when the ore does not extend down to a main level. In this case a sublevel is opened at the base of the ore for the full length of the ore body, which is rarely over 125 feet long. A raise from the main level is put up to each end of this sublevel; one of these raises is used as a manway and the other as a manway and chute. This sublevel corresponds to the first sublevel in the method described in the preceding paragraph, and the raises and sublevels are opened in the same manner as described, but in this case there are no hoppers or cones. The ore broken in the stope falls to the first sublevel and is hauled by a scraper to the chute. This makes it possible to break chunks easily, and eliminates blasting in the chutes, which is the cause of much delay in the method first described.

The tail block of the scraper is attached to a piece of five-eighths-inch wire rope, which is wound on a small hoist at the top of the manway opposite the chute and scraper hoist. Before blasting, the tail block is hauled to the scraper hoist to be out of the way of the blast, but the five-eighths-inch rope is left in the stope. As the ore is not hard the rope is seldom broken by the blast. When it is broken, however, a light line tied to a small chunk of ore is thrown across the stope by hand, and the wire rope is pulled after it. In no case does a man have to go out in the stope.

This scheme is satisfactory only in rooms not over 125 feet in length. In longer rooms the second manway should come up in a pillar in the middle of the room, and the ore can be pulled both ways from this point to chutes at both ends of the stope.

UNDERGROUND TRANSPORTATION

In putting up raises two side-sets of ground are taken out on the side of the drift, and the chute is built on top of 9-foot legs. These side sets provide a place for the air hoist that is used for hoisting timber, and allow the foot of the ladder to be kept back from the side of the main haulageway. The chutes are built of 3-inch plank and are closed by stopper-boards.

In drifting, rock is loaded into 36-cubic foot rocker-dump cars, but for loading at chutes on main levels the standard cars are gable-bottomed, and have a capacity of 65 cubic feet. These cars will probably be replaced soon by rocker-dump cars of the same capacity.

The locomotives are of the trolley type, weigh 6½ tons, and have two 37½ hp. series motors. The power circuit is 250-volt. Both locomotives and cars are equipped with half-size automatic couplers, and every locomotive carries a 5-ton jack and a pair of rerailers.

The track is of 30-inch gauge and is laid with 40-pound rails with welded bonds. Block signals are used on all levels where more than one locomotive is in service. In all there are over 12 miles of main-line track in use.

At the shaft there is a large storage pocket with compartments for rock (waste) and two kinds of ore. Below these are measuring pockets, each holding 4 tons, which is the capacity of the skip.

PERCENTAGE OF EXTRACTION

Extraction is estimated at 90 per cent, and probably another 10 per cent is spoiled by included rock or falls of rock from the back or sides of stopes. These losses are deducted from the gross tonnage in calculating ore available for mining.

CONTRACT SYSTEM

All miners are paid on a contract basis, the unit for price calculations being a 4-ton car. Except in the substopes and raises every gang is provided with a scraper or a mechanical loader, and the contract prices range from 75 cents to $1.60 per car. The miners pay for explosives, carbide, picks and shovels, lamps, and small accessories. The company furnishes drills and steel, compressed air and electricity, lights, loading equipment, and timber. The miners do their own timbering and blasting.

VENTILATION

Ventilation is natural and is excellent. Mechanically operated doors are installed at the proper places to control the flow of air, and in dead ends small fans are used to blow the powder smoke from the breast. Both canvas tubing and the 10-inch spiral riveted pipe are used for ventilating ducts.

FIRE HAZARDS AND SAFETY WORK

Although the danger of fire is not great, fireproof self-closing doors are installed at convenient places by means of which the air current can be stopped until all the men are out of the mine. These doors are closed by counterweights and are held open by latches which can be tripped by opening a valve between the main air pipe and a special pipe line at any level in any shaft or on surface.

A stench warning signal system has been installed, and fire-helmet crews receive regular training from both the company's safety department and the U. S. Bureau of Mines Mine-Rescue Car.

These men also receive training in first-aid, and are provided with a full quota of rescue apparatus.

Much attention is paid at this mine to safety work, and a remarkable record of over 15 months of operation without a single lost-time injury has been made. Cleanliness and light are required everywhere, on surface and underground, and discipline is excellent.

All the shaft stations are whitewashed and well lighted, and all tools are kept hung up. Every man is required to wear a hard hat and must wear goggles when doing certain classes of work. All fuses are capped at centrally located stations on each level. The lengths of fuse are standardized, and the capping is done with a safety-cap crimper. Fuses are carried and stored in special sheet-iron circular cans 10 inches in diameter and 3 inches deep, and all powder is distributed from fireproof magazines underground. It is by giving attention to these details that such fine results have been accomplished.

MINING COSTS

Table 1.- Summary of costs

Name or number of mine: Mine No. 2 Marquette County, Mich. Period covered: Year of 1928. Tons ore hoisted during period! 120,000. Mining method: Sublevel stoping.

Underground Costs per Ton of Ore Hoisted

	1. Labor	2. Supervision	3. Compressed-air drills and steel	4. Power cost	5. Explosives	6. Timber	7. Other supplies	8. Total
Development:								
In ore ----------	0.037	0.010	0.017	0.007	0.012	0.006	0.010	0.099
In rock ---------	.055	.004	.030	.040	.006		.037	.172
Mining ---------------	.180	.025	.030	.047	.050	.010	.075	.417
Transportation (underground) -------	.134	.003	-	.007	-	-	.005	.149
General underground expense ------	.150	.003	-	-	-	.020	.020	.193
Surface expense (directly applicable to underground operation) ---	.010	-	-	.040	-	.009	.007	.066
Total	0.546	0.045	0.077	0.141	0.068	0.045	0.154	1.076

Table 1-A.- Summary of costs

Name or number of mine: Mine No. 2, Marquette County, Mich. Period Covered: Year of 1928. Tons ore hoisted during period: 240,000. Mining Method: Top-slicing.

Underground costs per ton ore hoisted

	1. Labor	2. Supervision	3. Compressed-air drills and steel	4. Power Cost	5. Explosives	6. Timber	7. Other supplies	8. Total
Development:								
In ore	0.037	0.010	0.017	0.007	0.012	0.006	0.010	0.099
In rock	.035	.004	.030	.040	.006		.037	.152
Mining ------	.370	.025	.045	.047	.075	.070	.075	.707
Transportation (underground)	.134	.003	-	.007	-	-	.005	.149
General underground expense	.150	.003	-	-	-	.020	.020	.193
Surface expense (directly applicable to underground operation)	.010	-	-	.040	-	.009	.007	.066
Total	0.736	0.045	0.092	0.141	0.093	0.105	0.154	1.366

Table 2 - SUMMARY OF COSTS IN UNITS OF LABOR, POWER & SUPPLIES

Name or Number of Mine - No. 2 Mine, Marquette County, Mich. Period Covered - Year 1928.
Tons Ore Mined and Hoisted - 364,945

Mining Method - Top Slicing & Sub-Level Stoping.

	DEVELOPMENT	MINING(STOPING)	TOTAL
A. Labor (Man-Hours per Ton)			
Breaking (Drilling & Blasting)	.033	.053	.086
Timbering (or), (and) Filling	.174	.142	.316
Mucking	.049	.159	.208
Haulage and Hoisting	.021	.196	.217
Supervision	.016	.034	.050
General	.050	.102	.152
Total Labor Underground	.343	.686	1.029
Av. Tons per Man per Shift	23.32	11.66	7.77
Labor, Per Cent of Total Cost			60.8%
B. Power and Supplies.			
Explosives (lbs. per ton)	.229	.244	.473
(kind and grade)	60% L.F. Ammonia Gel.	60% L.F. Ammonia Gel.	
Timber (Lin.Ft. per Ton of Ore)			.55
Total Power (In K.W. Hr. or H.P. Hrs. per Ton)			
(1) Air Compression			4.24
(2) Hoisting			2.30
(3) Pumping			1.73
(4) Lighting and Haulage			.94
(5) Miscellaneous			.13
Total Power K.W. Hr. per Ton			9.39
C. Per Cent of Total Cost	11.15	88.85	100.00

Table 3. - Detail of costs in units of labor, power, and supplies

DEVELOPMENT

	Drifting	Cross-cutting	Raising
Size of excavation (sub stopes)	4 by 6 ft.	4 by 6 ft.	
Main levels	10 by 10 ft.	10 by 10 ft.	6 by 11 ft.
Timbered or not	10 by 10 ft. ore drifts, timbered 10 by 10 ft. rock drifts, not timbered 4 by 6 ft. ore drifts - not timbered on subs in substopes		Timbered
Physical properties of ore	Soft	--	--

A. Labor (man hours per foot): Main level - ore and rock drifting

Breaking (drilling and blasting)	0.83
Timbering	.50
Mucking	2.00
Haulage and hoisting	1.33
Supervision	.08
Total labor	4.74

Feet per 8-hour man-shift ---------------- 1.69

B. Power and supplies (per foot):

Explosives (lbs. per ft.) in large drifts ----------25.5

C. Percentage of total cost:

Labor	70.6
Supplies	29.4

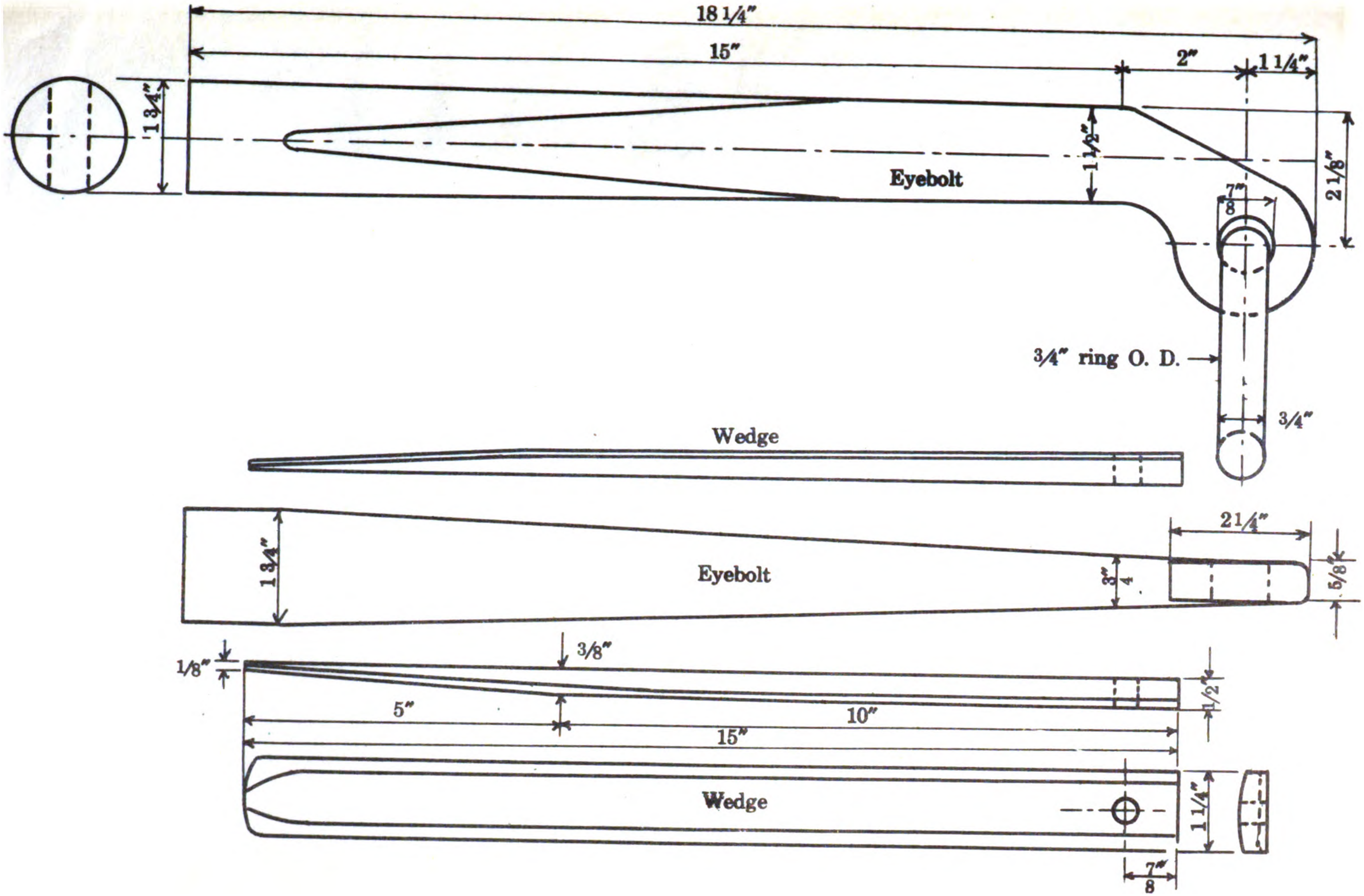

Figure 7. – Eyebolt and wedges